Flavor Asymmetry in Hyperons and Drell-Yan Processes *

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Abstract

SU(3), baryon octets and a meson cloud model are compared for the flavor asymmetry of sea quarks in the Σ^+, as an example. Large differences are found, especially between SU(3) and the meson cloud model. We suggest Drell-Yan measurements of $\Sigma^+ - p$ and $\Sigma^+ - d$ to test the prediction of various models. We use the meson cloud model to predict both valence and sea quark distributions.

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The predicted [1] and measured [2], [3] flavor asymmetry of the proton, e.g., $\bar{d}$ / $\bar{u}$ or$(\bar{d}-\bar{u})$ have awakened considerable interest. A simple explanation first proposed by A. Thomas [1] was in terms of the pion sea surrounding the quarks in the proton. Since a proton consists of uud quarks surrounded by a π^0 or udd quarks surrounded by a $\pi^+(u\bar{d})$, an excess of $\bar{d}$ over $\bar{u}$ is to be expected. This model has been examined quantitatively [4] and can explain the Gottfried sum rule deficiency [5] and the $(\bar{d}-\bar{u})$ measured in Drell-Yan p -p collisions [2], [3] We have examined the expected flavor asymmetry of $\Sigma^\pm$ baryons. [6] We find large differences between the expected asymmetry on (1) the basis of SU(3), (2) a baryon octet $\otimes$meson octet model, and (3) the meson cloud model. Thus, a measurement of the sea asymmetry via the Drell-Yan reactions $\Sigma^\pm + pand\Sigma^pm + d \rightarrow l^+ + l^- + X$ can be used to differentiate between the models.

I will use the Σ^+ to illustrate the thesis. It is very easy to understand the difference between SU(3) and the meson cloud model. In SU(3) we have $u\bar{u}$ in the $p \Rightarrow u\bar{u}$ in the Σ^+, $d\bar{d}$ in the $p \Rightarrow s\bar{s}$ in the Σ^+, $s\bar{s}$ in the $p \Rightarrow d\bar{d}$ in the Σ^+. Thus, we have $\frac{\bar{d}}{\bar{u}}(\Sigma^+) = \frac{\bar{s}}{\bar{u}}(p)$ in SU(3). On the other hand, one expects a larger $\bar{d}/\bar{u}$ ratio in the Σ^+ than in the proton in the meson cloud model because Σ^+ can decompose into $\Sigma^+\pi^0, \Sigma^0\pi^+, \Lambda^0\pi^+$, and $p\bar{K}^0$, where all but the first case $(\Sigma^+\pi^0)$ correspond to an excess of $\bar{d}$ quarks.

At $x \sim 0.2$, the measured ratio $\bar{u}/\bar{d} \approx 1/2$ [2] (or 2/3 [3]); also $\frac{\bar{s}}{\bar{u}+\bar{d}}(p) \approx 1/4$. This gives $\frac{\bar{d}}{\bar{u}}(\Sigma^+) = \frac{\bar{s}}{\bar{u}}(p) \sim 0.7$ in SU(3); this value is < 1, in contrast to the meson cloud model.

We have also examined a proton made up of a baryon octet $\otimes$ a meson octet with a ratio of SU(3) couplings F/D = 0.6. A summary is presented in table I for $x \simeq 0.2$.

TABLES

TABLE I. Predicted and measured flavor ratios. The experimental column refers to the proton; all other ones are predictions for the Σ^+.

Flavor ratios	Experim.	SU(3)	Octets	Meson Cloud
$\frac{\bar{u}}{\bar{d}}$(p),$\frac{\bar{u}}{\bar{s}}(\Sigma^+)$	$\frac{1}{2}(\frac{2}{3})$	$\frac{1}{2}(\frac{2}{3})$	0.29	$\sim \frac{1}{2}$
$\frac{\bar{s}}{\bar{u}+\bar{d}}(p)$, $\frac{\bar{d}}{\bar{u}+\bar{s}}(\Sigma^+)$	$\sim \frac{1}{4}$	$\sim \frac{1}{4}$	0.42	~ 0.1
$\frac{\bar{u}}{\bar{d}}(\Sigma^+)$	?	$\sim \frac{4}{3}$	0.54	~ 0.3

Deviations from SU(3) symmetry can also be expected in the distribution function of valence quarks [6]. For instance, on the basis of a quark- diquark model, we predict that $\frac{s}{u}(\Sigma^+)$ is more than three times as large as the SU(3) value at $x \sim 0.7$.

Appropriate for this conference in honor of Josef Speth's 60th birthday, we have used the Sullivan process to compute the valence and sea quark distribution functions in the Σ^+. We have

$$\Sigma^+ = \sqrt{Z}[\Sigma^+_{bare} + \sum \int dy d^2k_\perp \phi_{BM}(y, k_\perp^2) B(y, \vec{k}_\perp) M(1-y, -\vec{k}_\perp)] \qquad , \tag{1}$$

with $M = \pi^+, \pi^0, \bar{K}^0$ and $B = \Lambda^0, \Sigma^0, \Sigma^+, p$.

We carry out our calculation in the infinite momentum frame with time ordered perturbation theory [4] and pseudoscalar coupling. We neglect masses above 1700 MeV and thus do not consider $\Delta\bar{K}$ states. We have respected the necessary symmetries. [4]For instance, we have

$$q(\Sigma^+, x) = \sqrt{Z}(q_{bare} + \delta q) \qquad , \tag{2}$$

with

$$\delta q(\Sigma^+, x) = \sum \int_x^1 f_{MB}(y) q_M(\frac{x}{y}) \frac{dy}{y} + \int_x^1 f_{BM}(y) q_B(\frac{x}{y}) \frac{dy}{y} \qquad , \tag{3}$$

and require

$$f_{MB}(y) = f_{BM}(y) \tag{4}$$

In order to take finite sizes into account, we introduce Gaussian form factors with the size set by $\Lambda = 1.08 GeV$ [4]. We have studied the dependence of our results on Λ; the changes are quantitative, but not qualitative. Coupling constants are taken from Dumbrajs, Koch, and Pilkhun. [7] We assume that 20% of the mesons' momenta are carried by sea quarks.

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or the s quark distribution in the $\bar{K}^0, \Lambda^0$, and Σ, we take both SU(3) and a shifted distribution which takes the higher mass of the s quark into account.

For the proton, we find that our calculation with the omission of the Δ and higher mass (e.g., vector) mesons gives an acceptable fits for the $(\bar{d}-\bar{u})$ experimental data. [3] However, $\bar{d}/\bar{u}$ shows no decrease at higher values of x, contrary to experiment; see, however [8]

The results of our calculation are shown in the following figures. Fig. 1 shows the momentum fraction carried by u and $\bar{u}$ quarks; Figs. 2 and 3 are the same for s and d quarks; Figs. 4 and 5 show the valence quark momentum distributions. Figs. 6 and 7 show $\bar{d}/\bar{u}$ and $(\bar{d}-\bar{u})$ distributions. Fig. 8 is the momentum fraction $x(\bar{d}-\bar{u})$. Figs. 9 and 10 compare the Σ^+ and proton $\bar{r} \equiv \bar{d}/\bar{u}$ and $(\bar{d}-\bar{u})$. It is readily apparent that $(\bar{d}-\bar{u})$ is larger in the Σ^+ than in the proton. The ratio $\bar{r} \equiv \bar{d}/\bar{u}$ in the Σ^+ vs. p is seen to begin at approximately 1 at small x and to climb to 2 at $x \sim 0.35$.

In conclusion, the ratio $\bar{r} \equiv \bar{d}/\bar{u}$ in the Σ^+ may be < 1, as in (SU(3) or > 1 as in the meson cloud model. We have calculated both $q(x)$ and $\bar{q}(x)$ in the meson cloud model and have confirmed that $\bar{r}(\Sigma^+) > \bar{r}(p)$ in this model.

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List of Figures

Fig. 1. Momentum fraction carried by sea u and $\bar{u}$ quarks. The dashed curve here and elsewhere corresponds to the bare sea.

Fig. 2. Momentum fraction carried by sea s and $\bar{s}$ quarks.

Fig. 3. Momentum fraction carried by sea d quarks. The figure for $\bar{d}$ quarks is similar.

Fig. 4. Momentum fraction carried by valence u quarks.

Fig. 5. Momentum fraction carried by valence s quarks.

Fig. 6. The distribution of the ratio $\bar{d}/\bar{u}$.

Fig. 7. The distribution $(\bar{d}-\bar{u})$ for the Σ^+.

Fig. 8. The momentum fraction x $(\bar{d}-\bar{u})$.

Fig. 9. The ratio $\bar{r}(\Sigma^+)/\bar{r}(p)$.

Fig. 10.The ratio $(\bar{d}-\bar{u})(\Sigma^+)/(\bar{d}-\bar{u})(p)$.